INDOOR AIR QUALITY ASSESSMENT

Tadgell Hall Elementary School
7 Berkshire Avenue
Belchertown, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program

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Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Tadgell Hall Elementary School, 7 Berkshire Avenue, Belchertown, Massachusetts. A visit to conduct an indoor air quality assessment was made to this school by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program on February 27, 2004. Mr. Holmes was accompanied by Judy Metcalf, Health Officer for the Quabbin Health District and Robert LaChance, Director of Facilities, Belchertown Public Schools. The request was prompted by reports of exacerbation of asthma believed to be caused by environmental conditions in the building.

The school is a multi-level brick building originally constructed as a nursery in the early 1960's. The building underwent interior renovations and the building was subsequently occupied by elementary school staff in 1992. The school contains general classrooms, cafeteria, art room, gymnasium and office space. The Massachusetts Emergency Management Agency (MEMA) occupies office space on the ground level, at the rear of the building.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

This school houses approximately 180 first and second grade students with a staff of approximately 25. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million of air (ppm) in eight of ten areas surveyed, indicating inadequate ventilation in the majority of areas surveyed. Fresh air in classrooms is supplied by a unit ventilator (univent) system. Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 1) and return air through an air intake located at the base of each unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. The majority of univents were not operating during the assessment. Obstructions to airflow, such as papers and books stored on univents and items placed in front of univent returns, were seen in a number of classrooms (Picture 2). In order for univents to provide fresh air as designed, they must remain operating while rooms are occupied. In addition, intakes must remain free of obstructions.

Exhaust ventilation in some classrooms consists of wall-mounted vents (Picture 3) powered by rooftop motors. The exhaust system was not drawing in a number of areas surveyed, indicating that motors had been deactivated or non-functional. Classrooms that were formerly nurse's stations were designed to provide exhaust ventilation via passive vents installed in the hallway doors. As fresh outside air was mechanically introduced by univents, the rooms would become pressurized, forcing exhaust air out the passive door vents. However, these door vents are now sealed (Picture 4), preventing air exchange as originally designed. Without adequate exhaust ventilation, excess heat and environmental pollutants can accumulate and lead to indoor air complaints.

Mechanical ventilation in ground floor areas (cafeteria, gym, art room) is provided by an air handling unit (AHU) located in a mechanical room (Picture 5). Fresh air is distributed by ceiling or wall-mounted air diffusers via ductwork. Return air is drawn into wall or ceiling exhaust vents ducted back to the AHU. This system was operating during the assessment.

In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 71 ^{o} F to 78 ^{o} F, which were within the BEHA comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 12 to 19 percent, which were below the BEHA comfort range. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several classrooms had a number of plants. Moistened plant soil and drip pans can be a source of mold growth. Plants are also a source of pollen. Plants should be located away from the air stream of ventilation sources to prevent the aerosolization of mold, pollen or particulate matter throughout the classroom. Plants and shrubbery were also noted outside the building in close proximity to exterior brickwork. The growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. *Carbon monoxide should not be present in a typical, indoor environment.* If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10 µm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 6 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 8 to 40 $\mu g/m^3$. Although PM2.5 measurements were above background, they were below the NAAQS of 65 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were non-detect (ND) (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, the TVOC air measurements reported are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While TVOC levels were ND, materials containing VOCs were present in the school.

An elevator shaft located on the ground floor contained several containers of hydraulic fluid (Picture 6). A slight odor of hydraulic fluid was detected upon entering the mechanical room. BEHA staff recommended that maintenance staff ensure that containers of hydraulic fluid and other hazardous substances be securely sealed after use to prevent the migration of odors. The movement of the elevator in the shaft can act like a piston, pressurizing and depressurizing air in the elevator shaft, which can then force and draw odors into other areas of the building. Several classrooms contained dry erase boards and dry erase markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs (e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can be irritating to the eyes, nose and throat. Spray-cleaning products were found on countertops and in unlocked storage cabinets beneath sinks in classrooms. Cleaning products contain chemicals that can be irritating to the eyes, nose and throat. Cleaning products should be stored properly and kept out of reach of students.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and lead to off-gassing of VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provide a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. Accumulated dust was also observed on classroom exhaust/return vents. Exhaust vents and personal fans should be cleaned periodically to avoid aerosolizing accumulated dust.

Finally, one of the issues prompting the inspection was concerns of environmental tobacco smoke (ETS). As mentioned, the rear of the building is used for office space not associated with school operations. Occupants of this part of the building reportedly smoke outside of the rear of the building. An air intake for offices appears to be located on the exterior wall in this area (Picture 7). The proximity of the vent to the smoking area can lead to possible entrainment of ETS into occupied areas of the building. The offices and the school share a common wall on the ground floor, near the cafeteria. Two passive vents were observed in this shared wall (Picture 8). These passive vents allow free transfer of air (and possible smoke odors) between the offices and the school.

Conclusions/Recommendations

In view of the findings at the time of the assessment, the following recommendations are made:

1. Survey classroom univents to ascertain function and determine whether an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the school.
2. Operate all ventilation systems throughout the building (e.g., gym, cafeteria, classrooms) continuously during periods of school occupancy and independent of thermostat control to maximize air exchange. To increase airflow in classrooms, set univent controls to "high".
3. Inspect rooftop exhaust motors and belts for proper function, repair and replace as necessary.
4. Remove all blockages from univents and exhaust vents.
5. Consider providing mechanical exhaust or reinstall passive vents in classroom doors to provide air exchange.
6. Consider balancing mechanical ventilation systems every 5 years, as recommended by ventilation industrial standards (SMACNA, 1994).

7. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all non-porous surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
8. Remove plants away from univents. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.
9. Remove plant growths against the exterior wall/foundation of the building to prevent water penetration. Trim trees away from brickwork.
10. Ensure containers of hydraulic fluid in elevator shaft mechanical room are properly secured to prevent the migration of odors.
11. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
12. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
13. Store cleaning products and chemicals properly and keep out of reach of students.
14. Clean exhaust/return vents periodically to prevent excessive dust build-up.

15. Consider discussing the relocation of the smoking area in the rear of the building with MEMA staff. If not feasible, seal passive vents in cafeteria hallway to prevent smoke/odor migration.
16. Consider adopting the US EPA (2000) document, Tools for Schools, in order to provide self assessment and maintain a good indoor air quality environment at your building. The document is available at http://www.epa.gov/iaq/schools/index.html.
17. Refer to the resource manual and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These documents are located on the MDPH's website: http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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Picture 1

Univent Fresh Air Intake

Picture 2

Items on Univent Obstructing Airflow

Picture 3

Wall-Mounted Exhaust Vent

Picture 4

Sealed Passive Vent in Classroom Door

Picture 5

AHU in Ground Floor Mechanical Room

Picture 6

Containers of Hydraulic Fluid in Elevator Shaft Mechanical Room

Picture 7

Mechanical Air Vent and Smoking Area for MEMA

Picture 8

Passive Vents in Cafeteria Hallway

Tadgell Hall Elementary School **Indoor Air Results**

7 Berkshire Avenue, Belchertown, MA **February 27, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background (outdoors)	52	11	370	ND	ND	6			-	-	Clear skies, sunshine, NE winds 5-10 mph
4	76	15	956	ND	ND	15	19	Y	Y	Y	Window open, exhaust-off, UV off and obstructed by items on air diffuser, plants, cleaning products, TB
Kruse	78	16	946	ND	ND	20	25	Y	Y	Y	UV-off and blocked by furniture and other items
Art Room	72	12	620	ND	ND	9	0	N	Y	N	Dusty return vent-UV
Cafeteria	73	16	1210	ND	ND	11	80	Y	N	N	DO
Cafeteria Hallway				ND	ND				Y	Y	Passive vents between MEMA offices and school, periodic smoke odors reported

ppm = parts per million parts of air
µg/m3 = microgram per cubic meter
UV = univent
AD = air deodorizer
AP = air purifier

CD = chalk dust
DEM = dry erase marker
DO = door open
ND = non detect
PC = photocopier

PF = personal fan
TB = tennis balls
UF = upholstered furniture
UV = univent
WD CT = water damaged ceiling tile

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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									Supply	Exhaust	
7	73	18	1362	ND	ND	15	22	Y	Y	N	DEM, cleaning products
6	71	14	622	ND	ND	8	0	Y	Y	N	DEM, cleaning products
1	74	19	1158	ND	ND	20		Y	Y	N	DEM, plants
5	73	18	900	ND	ND	12	23	Y	Y	N	DEM, cleaning products
2	75	19	1335	ND	ND	40	1	Y	Y	N	Occupants at lunch
3	75	19	1254	ND	ND	33	2	Y	Y	N	20 occupants gone 15 min (lunch), dry mops/sweeping

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